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DEVELOPMENT OF A LIGHT-WEIGHT LOW COST SELF POTENTIAL UNIT

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FOREWORD

The staff and faculty of the Mineral Industry Research Laboratory is proud to have sponsored the research which has led to this report by Kenneth L. Zonge, Assistant Professor of Electrical Engineering, Department of Electrical Engineering and part time employee of the Geophysical Institute, University of Alaska. This project was developed through consultation with Mr. Lawrence E. Heiner, Assistant Mineral Engineer, Mineral Industry Research Laboratory.

Refinement in design of a self potential unit used in a geophysical prospecting technique by prospectors in their search for economic mineral deposits truly conforms with the major objective of the Laboratory - that of assisting in the development of the mineral resources of Alaska. Thus, through the piercing eyes of science and mineral engineering research, hidden deposits of minerals will be found that will allow further increases in the economy of the community, state and nation.

E. H. Beistline

E. H. Beistline, Dean
College of Earth Sciences
and Mineral Industry

ABSTRACT

A lightweight, low cost self-potential unit has been developed using solid state components. The parts for the basic unit including batteries, copper sulfate pots, and hookup wire costs approximately $70.00. The device is instant reading and weighs two pounds. The batteries used have a shelf life of ten years and an estimated operation life (based on continuous use for ten hours per day) of sixty days. This instrument was developed specifically for the Alaskan prospector who is concerned with weight and cost of field instrumentation.

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INTRODUCTION

The self-potential method exploits the natural voltages generated in the ground and is an easy and inexpensive geophysical aid in prospecting.

If two non-polarizable electrodes are placed in the ground and connected to the terminals of a high impedance voltmeter, readings from fractions to hundreds of millivolts may be observed. Small background potentials of fractions of millivolts to a few tens of millivolts are always present and are generally due to contact potentials in the earth, induced potentials from ionospheric disturbances, or various other sources. Mineralization potentials on the order of hundreds of millivolts can be observed over sulfide deposits containing pyrite, chalcopyrite, or pyrrhotite, and also over deposits of graphite, pyrolusite, psilomelane, magnetite, and in come cases anthracite coal.

Self-potentials do not depend on any specific physical property but are due to chemical activities in the ground. Therefore they do not give much information about physical parameters associated with the source. Accordingly SP surveys should be accompanied by geological studies and other prospecting methods in the area of interest.

For more detailed information on the physical parameters of self-potentials, the reader is referred to the references.

SELF-POTENTIAL PROSPECTING METHODS

Electrodes and Cable

The biggest problem encountered in trying to measure self-potentials is in making a non-polarizing contact with the ground. Metal rods are unsatisfactory since the electrolytic action between the rod and ground usually generates potentials larger than the ones to be measured.

The simplest type of non-polarizing electrode is a porous pot containing a concentrated solution of copper sulfate ($CuSO_4$). A copper rod is placed in the pot and a cable is then run from the rod to the self-potential meter. This arrangement makes excellent contact with the ground (as long as one is not operating on a bare rock pile), has low internal resistance, and is especially suitable for use with the direct-reading unit as described in this paper.

Another very good, but extremely expensive electrode is the calomel (KCl - $HgCl_2$) electrode used in pH measurements. This probe can be adapted to self-potential work and makes a very dependable electrode. However, calomel electrodes have a high internal resistance and hence require a meter with an input resistance on the order of one to ten megohms. The meter described in this report would be suitable for use with calomel probes when used on the 0 - 100mv or

0 - 1000mv range.

There are few restrictions on the type of cable to use with this field device. Any cable which is lightweight, flexible, and which has a good insulating cover will suffice for self-potential field work.

Field Methods

Two procedures are available for Sp surveys; the base station and moving probe method which gives a relative potential plot, and the constant separation method which gives a plot of the potential gradient.

The first method involves setting up one probe as the base station and then moving the other probe through a predetermined grid. When the available cable is exhausted, another base must be established and corrections made for the difference in potential between the two bases. For example, if the potential of a point using the first base is P_1 and the potential of the same point using the new base is P_2 then the difference in potential between base 1 and base 2 is $P_1 - P_2$. All readings from base 2 must be corrected by this amount to bring them into alignment with base 1. This procedure is repeated for subsequent base stations.

The second SP survey method involves moving electrodes along a grid and keeping a constant separation between them (usually 25 - 100 feet). This is accomplished in a leap-frog manner so that in progressing along a line the rear electrode occupies the position of the front electrode each time a move is made. In this manner one measures the difference in potential between the two probes, $P_2 - P_1$, which gives $\frac{P_2 - P_1}{L}$ as the average potential gradient at a point midway between the two probes where L is the separation distance.

Figure 1 compares the two methods showing a typical plot along a profile over an orebody.

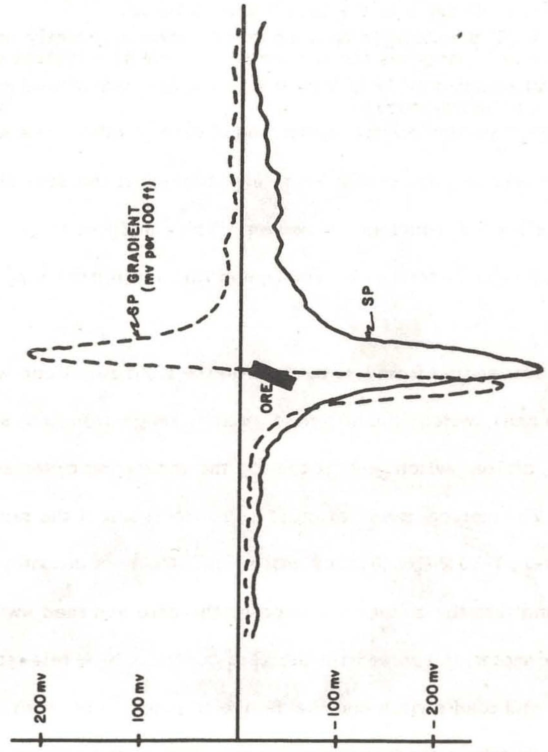

Figure 1. Sketch of Typical Self-Potential and Self-Potential Gradient Profiles Over an Orebody.

DEVICE DESCRIPTION

The self-potential meter described in this report was designed to be simple, compact, and fast reading. Consequently it was decided to use an electronic amplifier with a meter for the output as the simplest approach. The completed first model is shown pictorially in Figures 2 and 3 and schematically in Figure 4. This instrument was constructed with easily available components and if care is taken, the size of the device could be further reduced to about one half the size shown here, which is 3 x 5 x 7 inches. However, it was decided to use the size since the case is readily available and this instrument size is easy to handle.

Proceeding from left to right on the front panel one will find the push to zero switch, push to read switch, range selecting switch, zero control, off-on switch, and at the top the indicating meter and lead jacks.

The method of operation is as follows: Select the range of operation, i.e., 0-1, 0-10,0-100,0-1000 millivolts. Connect ground probes to meter and turn the meter on. Depress the zero and read switches and zero the meter on center with the zero control. Now release the zero control and read switch and the device is ready to be used.

To take a reading press the read button and note value on the meter. A deflection to the right indicates positive potential, to the

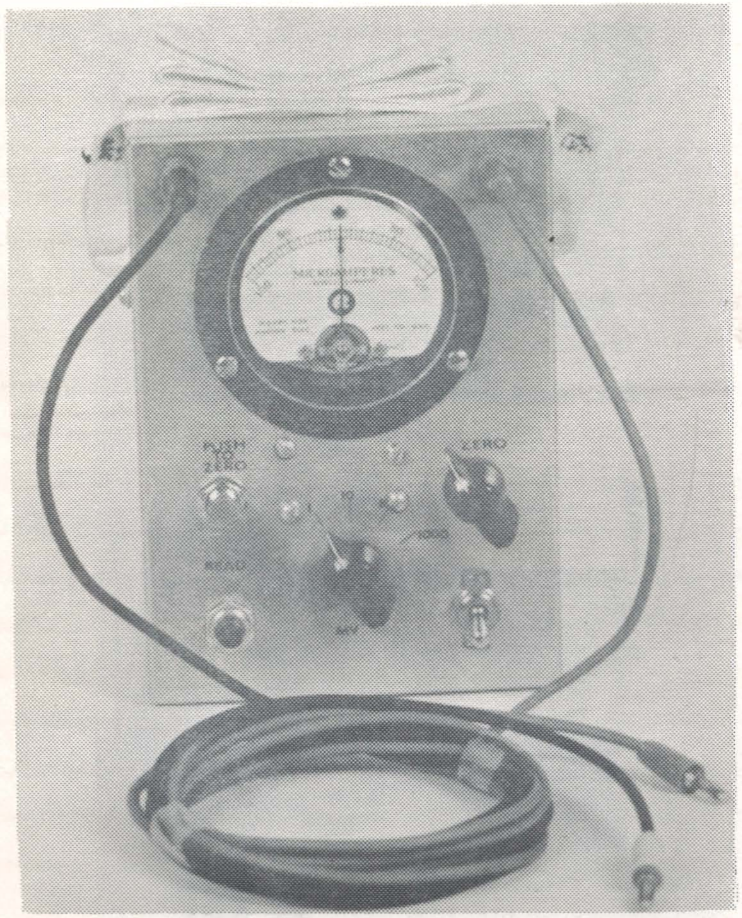

Figure 2. Front View of Self-Potential Meter.

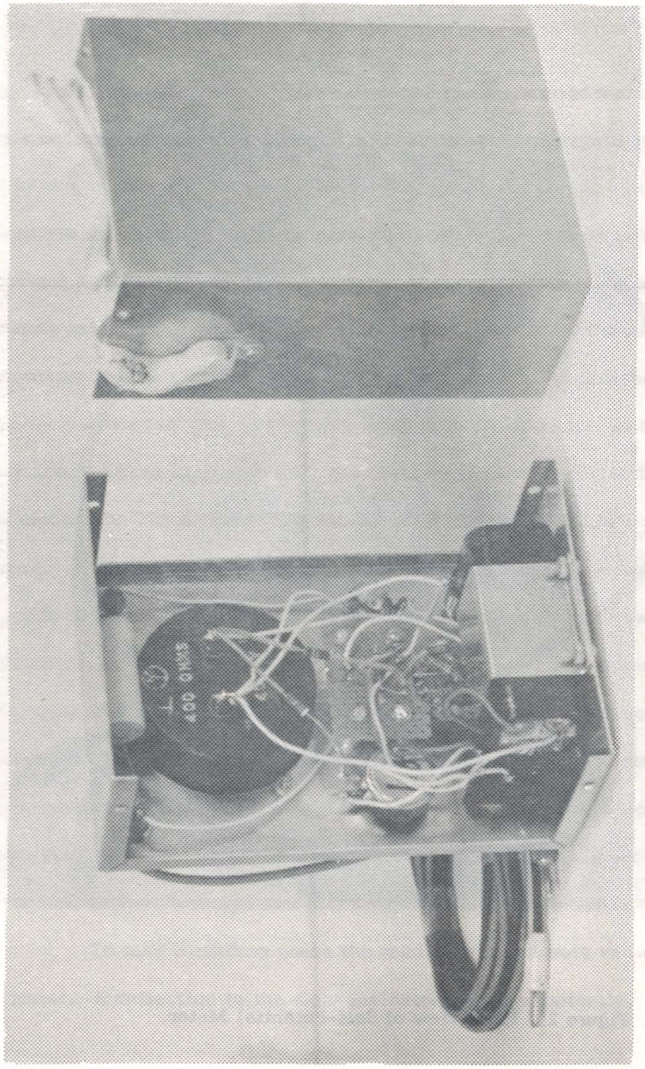

Figure 3. Interior View of Self-Potential Meter.

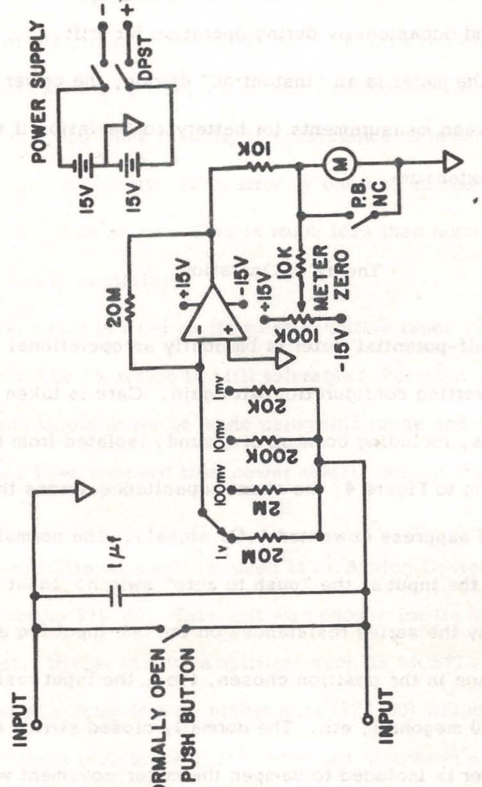

Figure 4. Device Schematic.

left negative. The meter zero should be checked when meter ranges are changed and occasionally during operation for drift.

Since the meter is an "instant on" device, the power may be turned off between measurements for battery conservation if the time intervals are extensive.

Theory of Operation

This self-potential meter is basically an operational amplifier used in the inverting configuration with gain. Care is taken to keep all connections, including common or ground, isolated from the meter case. Referring to Figure 4, the shunt capacitance across the input terminals is to suppress unwanted A.C. signals. The normally closed switch across the input is the "push to zero" switch. Input resistance is controlled by the series resistances on the one input leg and is equal to the resistance in the position chosen, i.e., the input resistance on the 1V scale 20 megohms, etc. The normally closed switch across the indicating meter is included to dampen the meter movement when not in use to prevent damage due to vibration, rough handling, etc. This is the "push to read" switch.

The power supply is made up of four 6.75V mercury cells, connected in series and tapped to give the voltage ratio indicated. This type of operational amplifier will operate on $\pm$ (10 - 16)V and the mercury cells used here will give $\pm$ 13.5V when connected as shown.

The accuracy of this instrument is controlled by the effective resistance of the ground connections and of course the electronics and indicating meter. If the porous pots used contribute an additional resistance of 1,000 ohms (usually the resistance is lower than this) then the measured potential is in error by one half of one percent when used on the 0 - 10mv range. This is much less than normal meter accuracies and is negligible.

If the meter is used on its most sensitive range (0 - 1mv) then the error would be 5% which is still tolerable. For most applications, measurements would never be made using this range and subsequently the range has been removed from newer models constructed by the author.

The operational amplifier used is an Analog Devices Model 105A presently costing $16.00. This unit was chosen for its high quality and low cost. Higher quality amplifiers such as MOSFET input devices may be used at a considerably higher cost ($75.00) which will give a much higher input resistance (10^{11} ohms) but also have a higher drift constant. However, it is felt by the author that this unit as described will suffice for all normal self-potential prospecting applications.

PARTS LIST

Following is a list of parts used including approximate prices for the more expensive parts.

	Quantity	Item	Cost
1.	1	Normally Open Push Button Switch	$1.00
2.	1	Normally Closed Push Button Switch	$1.00
3.	1	100-0-100 µA Meter	$10 - 30.00
4.	1	Operational Amplifier	$10 - 30.00
		(Analog Devices Model 105A)	$16.00
5.	1	4-Position Rotary Switch	$1.00
6.	1	Double Pole Single Throw Switch	$1.00
7.	2	Input Jacks or Connectors	
8.	1	100 K ohm Pot	$1.50
9.	4	6.75V Batteries. Everyready E-135N	$2.00 ea.
10.	6	Resistors: (1) 10 K, (1) 20 K, (1) 200 K, (1) 2 M, (2) 20 M.	
11.	1	1 µf Capacitor	
12.	1	3 x 5 x 7 x Aluminum Box	$1.50
13.	25-200 ft.	Flexidle Wire	$15.- 30.00 ea.
14.	2	Porous Pots (From Heinrichs Geoexploration)	$15.00)
15.		Copper Sulfate	$1 - 2.00/lb.

Addresses for the companies supplying the operational amplifiers and porous pots as used in this report are as follows:

Operational Amplifiers:

Analog Devices
221 Fifth Street
Cambridge, Mass. 02142
617/419-1650

Nearest Sales Office:

Seattle, Washington
206/723-7602

Porous Pots and Copper Sulfate:

Heinrichs Geoexploration
P. O. Box 5671
Tucson, Arizona 85703
602/623-0578

All other components can be obtained through a local electronics supply store. Any center reading panel meter can be used that has sufficient sensitivity; often usalbe panel meters can be found in surplus equipment.

To use a different meter the circuit must be adjusted according to the following formula:

$$I = \frac{1}{R_L + R_M}$$

Where: I = Full scale current reading of panel meter.

R_L = Load resistance or resistance on output of Amplifier (10,000 ohms for the device in this report).

R_M = Panel meter resistance.

For example, if one had a 25-0-25 microamp meter with an internal resistance of 5,000 ohms, the load resistance would be:

$R_L = \frac{1}{25 \times 10^{-6}} - 5{,}000$ ohms = 35,000 ohms. Or if a 1-0-1 milliamp meter with 50 ohms internal impedance were used the load resistance would be 950 ohms.

CONCLUSION

An introduction to the SP geophysical prospecting method, and a low cost, lightweight, portable self-potential unit have been described. The SP meter is simple enough for one to construct on his own providing he has a little knowledge of soldering and wiring techniques and uses proper caution.

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